A CONCEPT OF PORTABLE CHEM-DEMIL SYSTEM

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ABSTRACT

Because of the relief of tension between the western and eastern blocks, the phase-out of many arsenals' activities has gained momentum in the last few years. In these years, some waste materials including ordnance and chemical agents were routinely destroyed by neutralization or by burning in chambers. During the final phase-out, the number of designated areas to be decontaminated is expected to exceed the number of chem-demil facilities to be built. Many of them involve the decontamination of small sites. From the cost-effective viewpoint, a portable chem-demil system can be more attractive than a full-scale facility.

The proposed system may be similar to the USEPA Mobile Incinerator primarily built to test the adequacy of present technology for the destruction of organic contaminants in soils. It will include a number of trailers; the processing equipment may be contained in separate trailers for the destruction of chemical agents. In this system, the major component is the containment chamber holding the munitions with chemical agent and bursters. The chamber is mounted on a trailer capable of moving on public highways and byways. After being loaded into the chamber, the munitions will be opened and the chemical agent will be removed. The agent removed will be transferred to a vacuum holding tank for temporary storage. Both the chemical agent and decontaminated munition with burster will be removed, neutralized, and destroyed by others in a designated facility.

The chamber is designed to be blast-resistant and air-tight to prevent any chemical agent from leaking into the atmosphere even after a catastrophic event. It may include an airlock to safely load/unload the munitions and to provide a safe access for operating personnel to the chamber. To ensure system safety, an instrumentation system will be introduced for remote operation of the chamber. In addition, the instrumentation control must also be capable of sampling and monitoring the chamber environment to enhance public safety.

INTRODUCTION

In the last few years, the world of politics has gone through some dramatic changes. Among them, the most important event was the collapse of the Soviet Union, which relieved most of the tension between the western and eastern blocks. Since then conflicts have continued, however those are limited to regional areas, not global. These changes have also affected the Department of Defense. Undoubtedly, the relief of international threats and the continuous increase of the federal deficit have forced the administration to search for new approaches to cutting the defense spending. As a result, a series of actions, such as closing bases and arsenals, has been considered. These actions have accelerated the phase-out of many arsenals'

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activities. Some had already begun under the theme of environmental protection during the Bush administration.

Since the beginning of phase-out operations, many waste materials, including ordnance and chemical agents, were routinely destroyed by neutralization or by burning in chambers, and finally disposed of by burial. During the final phase-out, the number of sites to be decontaminated is expected to exceed the number of chem-demil facilities to be built. Many of them will involve the demilitarization of small sites. From the cost viewpoint, a portable chem-demil system should be more effective. This system is the center of discussion in this presentation.

The proposed system may be similar to the USEPA Mobile Incinerator. This incinerator was primarily built to test the adequacy of present technology for the destruction of organic contaminants in soils. For the proposed system, it will also include a number of trailers; thus the processing equipment may be contained in separate trailers for the destruction of chemical agents. In this system, the major component is the containment chamber holding the munitions with chemical agent and bursters. The mobile chamber will be used to open the munition, and extract the chemical agent. The agent will then be transferred to a vacuum holding tank which is located close to the chamber. Both the chemical agent and decontaminated munition with burster will be removed, neutralized, and destroyed by others in a designated facility.

The chamber is designed to be blast-resistant and air-tight to prevent any chemical agent from leaking into the atmosphere. To ensure system safety, an instrumentation system will be introduced for remote operation of the chamber. In addition, the control instrument must also be capable of sampling and monitoring the chamber environment to enhance environmental safety.

SYSTEM REQUIREMENTS

Derived from its scope, a portable chem-demil system should be developed on the basis of mobility, safety, and cost efficiency. General requirements for the system design are summarized as follows:

1. A containment chamber should be used to hold a munition with chemical agent and burster, and it should be capable of moving on roads.
2. The munition will be opened and chemical agent should be transferred to a vacuum holding tank connected to the chamber.
3. The chemical agent should be removed and neutralized within a reactor, which is located on a separate trailer or at a designated disposal site.
4. The empty and decontaminated munition will be transferred to a designated site for disposal.
5. Operations are remote and controlled by instrumentation which is required toensure a safe environment surrounding the chamber.
6. A schematic operational sequence of the system is shown in Figure 1.

COMPONENTS AND OPERATION

Based on the above requirements, major components required for the proposed system include the following items:

1. A containment chamber to contain munitions, operating devices for the munitions, and devices for extracting the chemical agent.
2. A vacuum holding tank for receiving the chemical agent and contaminated fluids.
3. A reactor for the neutralization of the chemical agent.
4. Mobile trailers for transporting the chamber, reactor, support equipment, etc.
5. Blast shield(s) to protect the chamber and its accessories, such as viewing systems and munition operating devices , from blast damage.
6. A complete viewing system for controlling chamber operations.
7. A complete utility system to support the performance of the proposed chem-demil system.
8. Instrumentation and controls required for system operation and environmental safety.
9. Others, including chamber penetrations, connecting ports, access door(s), etc.

Among them, the center of the chem-demil system is the munition agent access unit located in the containment chamber. A schematic arrangement of the munition agent access unit with vacuum holding tank is illustrated in Figure 2.

CONTAINMENT CHAMBER

The containment chamber will be a steel pressure vessel, which is designed to withstand an overpressure environment associated with an accidental explosion of 13 pounds of TNT. Under the explosion, a maximum out-leakage of gas products should not be more than the safety limit prescribed by the governing agency. The chamber should remain intact (with deformation within the elastic range) and reusable after the event of explosion.

In addition, some special features should also be introduced in the design to ensure the safety integrity of the chamber. The goals are to keep the chamber dry and to prevent the explosive products from leaking out of the chamber. These special features are:

1. Providing a blast shield around the munition to prevent the (tumbling) chard or shrapnel from penetrating the chamber.
2. During the opening of munition and extraction of the chemical agent, a minicontainment is required to keep the chemical agent from spilling into the chamber space and contaminating the area.

Based on the operational requirements mentioned above, the conceptual chamber will have the following configuration:

1. Chamber space - 10 ft OD by 24 ft long horizontal cylinder.
2. Design pressure - 2,000 psi static pressure.

3. Shell thickness - 2.5 in. except for the access door.
4. Design code - ASME Section VIII.
5. Munition mounting - integrated with the blast shield and with dolly for munition transfer.

A typical chamber is shown in Figure 3.

BLAST SHIELD

A blast shield provided will prevent the munition fragments from damaging the chamber pressure boundary. This shield can also stop high-pressure impingement directly onto the chamber shell. As indicated in the previous section, this shield may have to serve as a minicontainment to confine the spill of chemical agent. It should also be decontaminable.

To minimize the effects of explosion at close range, the concept shown in Figure 4 can be adopted. In this case, a close-range blast shield may be introduced for each type of munition to suit its fragment characteristics. Taking a 155 mm projectile, for example, the fragments will fly off radially at 20-degree angles, and its end caps will fly off axially. Although the fragments would not tumble endwise, the shield should be arranged in such a manner to trap these fragments. On this basis, the close-range blast shield will consist of the following characteristics:

1. Two concentric steel sleeves, with equal thickness and a 1 in. separation in between, will have a total thickness of 4 inches.
2. The inner sleeve is separated from the munition surface by 1.5 inches.
3. End shields will be formed plates and will have a total thickness of 6 inches.
4. The close-range blast shield is open without containing ability.

Other types of blast shields, such as approved suppressive shields, can also be used as blast shields. Using suppressive shields, group 6 may be the logical choice. This shield has a size compact enough to suit our purpose, and it was primarily designed for the transport of munitions. The shield is designed to meet the following criteria:

1. Designed per - HNDM 1110-1-2.
2. Scaled distance Z - approximately 1.
3. Charge weight to volume ratio - approximately 0.23.
4. Size configuration - spherical shell with 4.75 ft diameter.
5. Shield with sufficient containment ability to confine the spill of chemical agent during munition opening operation.

Using suppressive shields, the chamber configuration may be reduced to a thinner shell, say to 1.5 in. This reduction is due to the suppressive effect provided by the blast shield. If the shield is capable of resisting both the impingement of high pressure (impulse) and the impact of primary fragments, the overpressure environment inside the chamber can be substantially reduced. The design pressure of the chamber becomes a quasi-static pressure of no higher

than 100 psi.

TRAILERS FOR TRANSPORT

Mobile trailers will serve as the major vehicle to transport the chem-demil system to the final disposal site. For the chamber trailer, its size is determined by the space demanded to meet both operational and blast-resistant requirements. The trailer must fit into a legal configuration and be hauled by a bonded carrier. A typical trailer used for mounting the chamber is shown in Figure 5. It consists of the following characteristics:

1. Capacity - approximately 100 tons.
2. Size - 12 ft wide by 13.5 ft high.
3. Support - hydraulic suspension system can equalize the load over many axles, subsequently being capable of carrying a heavier load.
4. Multiple trailers covered by secondary confinement enclosures can expand the chem-demil operation to include the munition opening/decontamination, neutralization, and supports.

MAJOR OPERATIONS

There are several operational subsystems required to form a complete portable system for the opening and decontamination of munitions. These subsystems include the opening of munitions, chemical-agent mobilization, viewing devices, and decontamination process. They are discussed in the following sections.

OPENING OF MUNITIONS

The purposes of opening the munition are i) to allow the entry of working fluid required for mobilizing the congealed chemical agent for extraction, and ii) to permit the entry of working fluid and distilled water for decontaminating the munition interior. Any opening technique, including tools and/or devices to be used, must be carefully chosen for the designated munition to ensure operational safety. In any case, the burster must be kept intact. If an open, close-range blast shield is considered, a minicontainment at the opening point should be considered to confine the spill.

CHEMICAL-AGENT MOBILIZATION

A chemical-agent mobilizing fluid must be compatible with the congealed, viscous, sticky chemical agent in the munition. It must be capable of mobilizing the agent. This fluid could consist of water, heated water, or solvent; and could be provided at high pressure. To mobilize the agent, the fluid will be pumped from a separate trailer to the inside of the munition. After mobilization, the agent with fluid is then transferred to the vacuum holding tank for temporary storage.

VIEWING SYSTEMS

Direct or indirect viewing is required for the opening operation of munitions. The viewing system must meet the following criteria:

1. Devices must be commercially available and replaceable.
2. Devices must have a long life cycle and minimal cost for replacement.
3. Devices must be decontaminable and meet low maintenance requirements.
4. Devices must be capable of withstanding an explosion.

The viewing system may consist of any or a combination of the following items:

1. A direct viewing uses an internal sacrificial CCTV camera with lighting from internal sacrificial lamps.
2. An indirect viewing uses an externally mounted CCTV camera aimed at the scene of interest through a connecting port. Replaceable internal mirrors could be used.
3. A direct viewing using a fiber optic cable contains image and lighting conductors feeding an externally mounted camera. It can be a single viewing head or multiple viewing heads.
4. A direct viewing uses an internal sacrificial CCTV camera with full pan-tilt-zoom-focus-iris controls in an environmental enclosure.

DECONTAMINATION

To ensure a safe working environment and mitigate public exposure to the hazardous agent, a complete decontamination process must be performed for any contaminated item before its final release from the operation. The requirements for the decontamination of munition after its opening operation must include:

1. Decontamination of the munition interior.
2. Decontamination of the chamber interior, if contaminated by the spill of chemical agent.
3 Flushing munitions and/or chamber with distilled water subsequent to decontamination.
4. Transferring all contaminated and flushing fluids to the vacuum holding tank for temporary storage.
5. Minimizing the amount of fluid needed to accomplish the decontamination process.

DISCUSSION

For the design of a portable chem-demil system, there are several issues which must be considered and resolved before final settlement of the system configuration. They are discussed and summarized in the following sections.

CHAMBER DESIGN

Several designs have indicated that each system can sustain both the blast pressure and fragment impact. In the suppressive shield group designs approved by the Department of Defense Explosive Safety Board, there are five groups (3, 4, 5, 6, and 81 mm) which meet the requirements for most applications to ammunition loading, assembly, and packing in the Munitions Production Base Moderation and Expansion Program. On the other hand, there are several blast chambers in existence, which were designed to account for both overpressure and fragmentation.

DOD Safety Approved Shields

1. Size Variation: one spherical (about 2.5 ft OD), one cylindrical (about 13 ft OD by 10 ft long), and 3 rectangular (about 10.4 ft x 11.5 ft x 16.4 ft long). Only Group 4 would satisfy the size requirement (10.4 ft x 11.5 ft x 16.4 ft long).
2. Hazard Parameters: one low blast with light fragmentation, one medium blast with severe fragmentation, two high blasts with moderate fragmentation, and one very high blast with light fragmentation. With severe fragmentation and high-order containment, none of them would satisfy the requirement. If Group 4 is to be used, a moderate blast resistance must be upgraded to complete containment.
3. Level of Protection: all satisfy Category I hazard requirement.

Other Existing Blast Chambers

There are so many existing blast chambers designed for specific purposes, notably by CHEMATUR/DYNASAFE/WEATHERLY. For the removal of bombs, typical existing blast chambers consist of the following configurations:

1. 5 ft spherical chamber - 1-1/2 in. thick wall, handling 40 pounds of TNT with 0.1% strain.
2. 3.5 ft spherical chamber - 1 in. thick wall, qualified for 10 pounds of TNT at 0.05% strain.
3. 8 ft diameter by 12 ft long cylindrical chamber, handling 5 pounds of TNT.

Conclusive Remarks

There is no firm evidence that the above systems totally satisfy the requirements specified for the chem-demil chamber. For total containment, the chamber must meet the following requirements:

1. To resist a high-pressure impingement associated with a blast.
2. To defeat fragments generated by an exploded munition.
3. To serve as a minicontainment to confine the spill of agent.

For safety approved shields, as mentioned in the TM 5-1300, specific shield requirements

may vary with applications and different operations. It is therefore necessary to modify the approved shields to adapt them to the operation under consideration. For the proposed usage, the most critical items to be considered may be the protection required to defeat fragments, and the determination of a venting system to relieve the overpressure. In light of these, a separate blast shield close to the munition may be the most practical mean to slow down the fragment attack on the chamber shell and consequently preserve the chamber pressure boundary.

Similarly, other blast chambers have not proved to be capable of defeating fragments produced by munitions, either. It is claimed by Weatherly that Dynasafe has conducted many tests on their firing range where they have kept the gas overpressure contained in the chamber for a long duration without <u>any</u> leakage. However, it did not address the following concerns which are critically related to public safety:

1. Zero chamber-shell perforation by fragments as a result of the an explosion of munition.
2. If the objective of no leakage for chemical agent is 10^{-6} cc/atm, the proof test for leaktightness is a major task! With the chamber shell under plastic deformation, the possibility of providing a 100 % gas tightness is questionable.

SUPPRESSIVE BLAST SHIELD

In light of the close-range blast shield previously discussed, the total wall thickness required to defeat the largest primary fragment will be about 2-3/4 inches if a safety approved shield of 4.75 ft-diameter spherical sphere is considered. This thickness exceeds what is provided by Group 6 (1/4 in. thick spherical shell). Because of this discrepancy, the shield must be either a double-walled or composite system. The composite system may be a combination of external reinforcing frames and the thin shell provided by Group 6. Between reinforcing frames, a venting system can be introduced to control leakage pressure into the chamber space.

DESIGN EXPLOSION ENVIRONMENT

Several methods can be used to prove that the chamber thickness can be further reduced from that derived in the conceptual design. Unfortunately, all this reduction is strictly based on the overpressure. Reduction, such as derived from Guerke, can be very misleading. This may be true for a bare charge because it does not require consideration of fragmentation effects. In the writer's opinion, the design environment must be considered in various stages of consequence summarized in the following:

1. Explosion of a munition in a blast shield (4.75 ft sphere) with venting ratio of 0.02:

Reflected overpressure -	7,000 psi
Maximum gas pressure -	940 psi
Duration -	49 ms
Fragment striking velocity -	2,350 ft/sec

Design fragment weight -	14 pounds
Presented area for use in striking velocity -	9.4 $in.^2$

2. Environment in the chamber containment after the explosion of munition

Leakage pressure into the chamber -	56 psi
No fragment flying off towards the chamber	

3. External impact and/or explosion due to a traffic accident

Impact forces -	TBD
Explosive overpressure -	TBD
Flying debris -	TBD

Because of these requirements, the reduction of overpressure is not important when designing the proposed chamber. The critical point is to have each chamber component, such as the blast shield or containment, properly designed for its own purpose in order to ensure system safety.

OTHER PROBLEMS ASSOCIATED WITH THE SYSTEM DESIGN

In addition to those discussed above, there are other potential problems remaining to be solved. They are listed as follows:

1. Leakage allowed under a catastrophic event - explosion.
2. Compatibility of agent containment and blast shield required.
3. Sampling and monitoring of chamber environment to ensure safety.
4. Anchorage of blast shield without affecting the chamber configuration.
5. Penetrations, blast doors, equipment and tools required for operation could be the governing factors for designing the chamber.

REFERENCES

1. TM5-1300, "Structures to Resist the Effects of Accidental Explosions," November, 1990.
2. HNDM 1110-1-2, "Suppressive Shields Structural Design and Analysis Handbook", November 1977.
3. Private Communications.

Figure 1 Schematic Operational Sequence

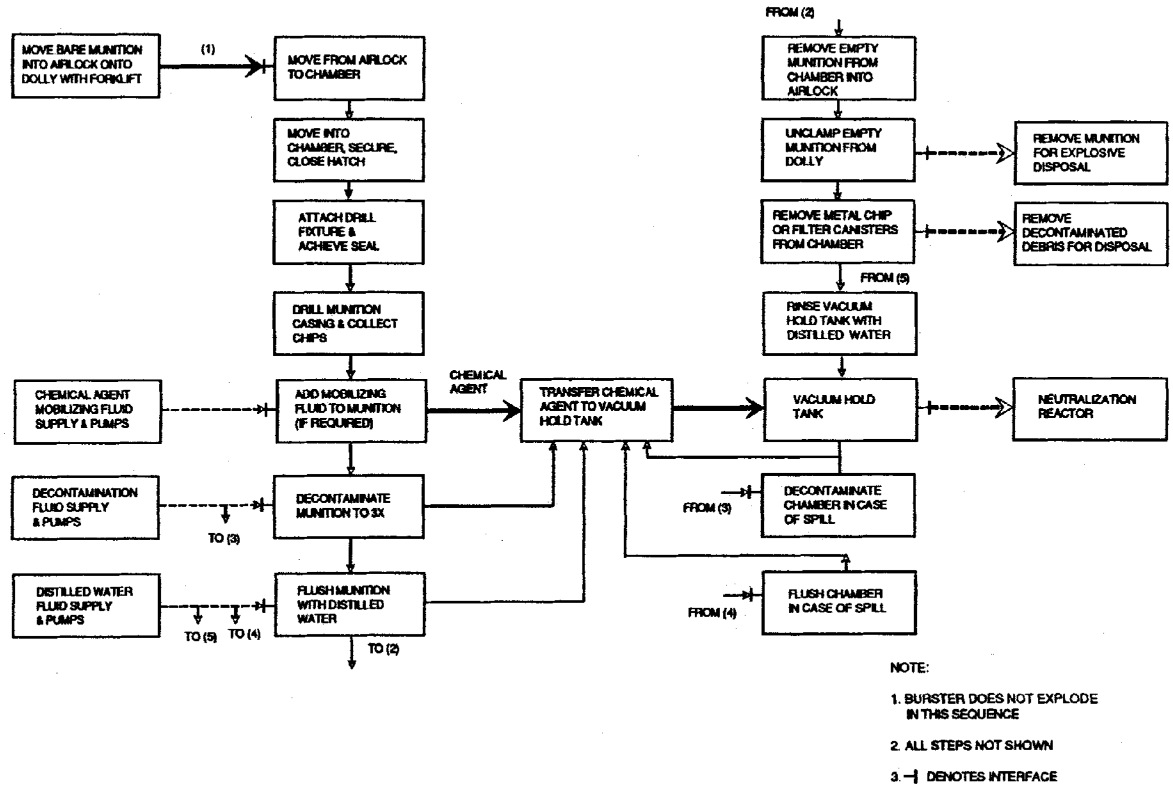

Figure 1   Schematic Operational Sequence

Figure 2 Schematic Arrangement

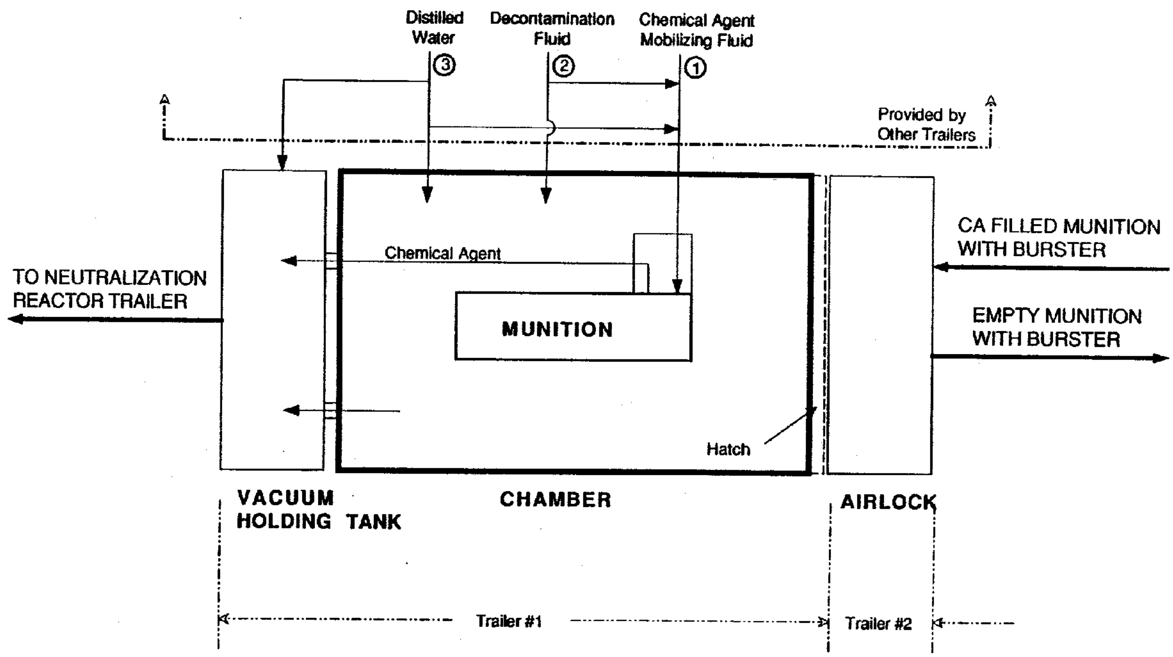

Figure 2 Schematic Arrangement

Figure 3 Typical Chamber Configuration

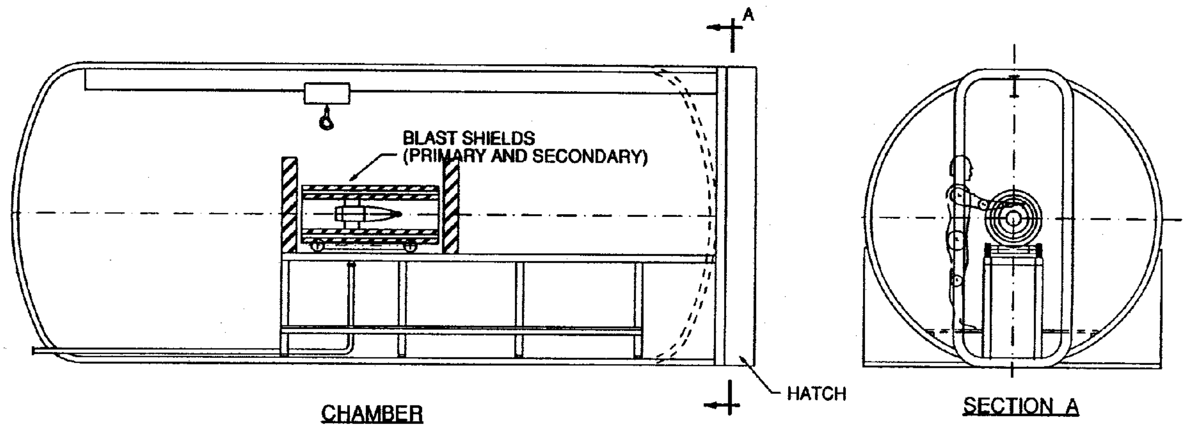

Figure 3 Typical Chamber Configuration

Figure 4 Close-Range Blast Shield

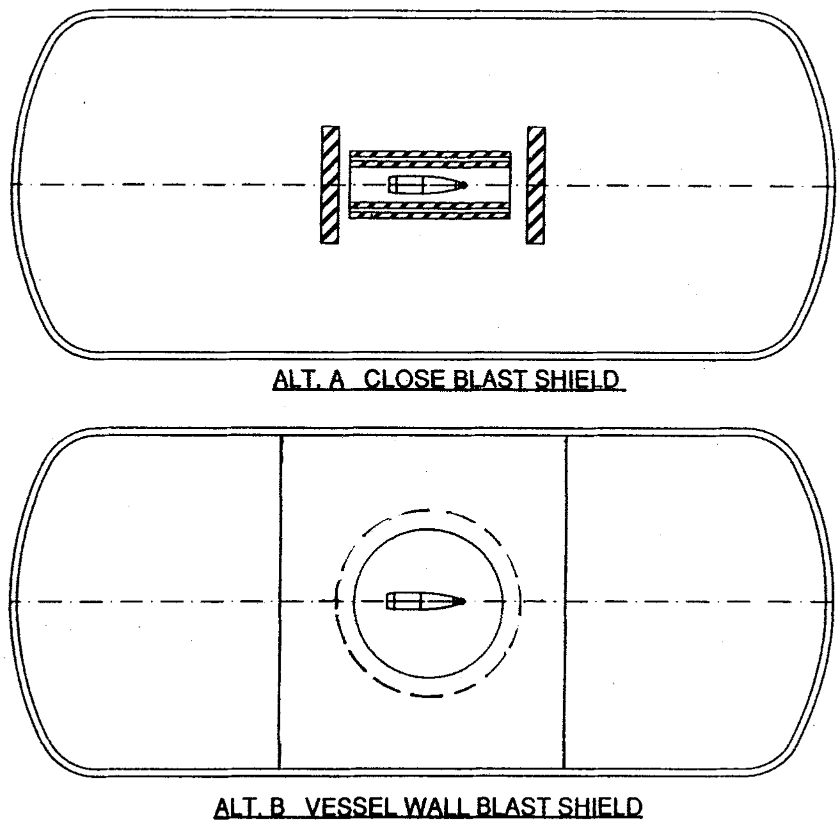

Figure 4   Close-Range Blast Shield

Figure 5 Trailer Configuration for Chamber

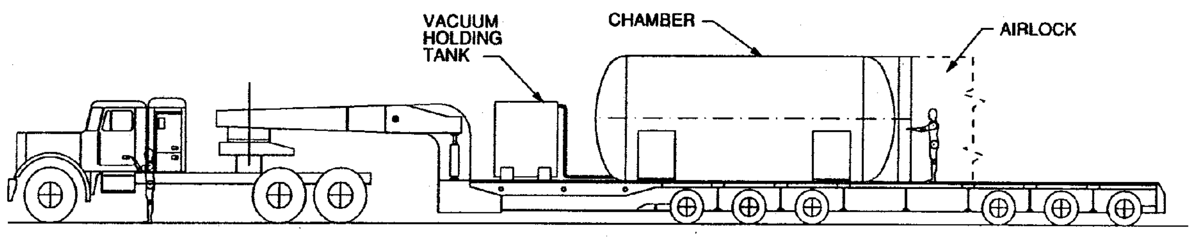

Figure 5   Trailer Configuration for Chamber